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(71) Applicant:
MURATA MANUFACTURING CO., LTD.
Nagaokakyo-shi Kyoto-fu 226 (JP)

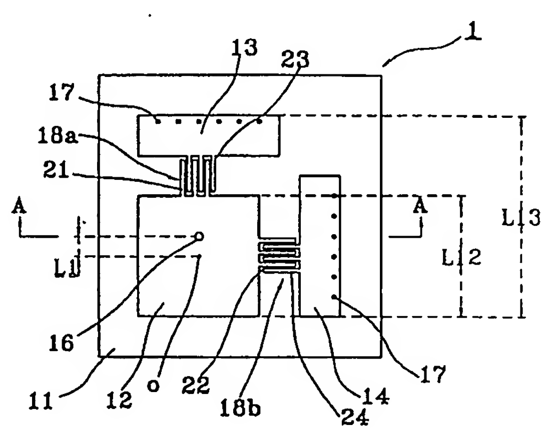
(72) Inventors:
- Itoh, Shigekazu
  Nagaokakyo-shi, Kyoto-fu (JP)
- Suzuki, Nobuhiko
  Nagaokakyo-shi, Kyoto-fu (JP)

(74) Representative:
Schoppe, Fritz, Dipl.-Ing. et al
Schoppe & Zimmermann
Patentanwälte
Postfach 71 08 67
81458 München (DE)

(54) Microstrip antenna

(57) A microstrip antenna (1) has a dielectric-made substrate (11). A first radiation-electrode (12) is formed on one main surface of the substrate (11). Second radiation-electrodes (13, 14) are formed on the periphery of the first radiation-electrode (12) with a spacing between the first radiation-electrode (12) and each of the second radiation electrodes (13, 14). A ground electrode (15) is formed on the other main surface of the substrate (11). A power-feeding through-hole 16 is provided at a position corresponding to the first radiation-electrode (12) on the substrate (11). A plurality of through-holes (17) are provided at positions corresponding to the second radiation-electrode (13) on the substrate (11). Capacitive-coupling portions (18a, 18b) are provided to capacitively couple the first radiation-electrode (12) and the second radiation-electrodes (13, 14), respectively. A connector (19), serving as a coaxial line, for feeding power to the first radiation electrode (12) is inserted into and past the feeding through-hole (16) from the other main surface of the substrate (11). The connector (19) is electrically connected to the first radiation-electrode (12) with solder (20a) and is fixed to the substrate (11) with solder (20a, 20b). The second radiation-electrodes (13, 14) are connected to the ground electrode (15) via the through-holes (17).

FIG. 1



EP 0 831 547 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to microstrip antennas and, more particularly, to a microstrip antenna which corresponds to a plurality of frequency bands and is also able to select the type of polarized wave.

2. Description of the Related Art

A conventional microstrip antenna will now be explained with reference to Figs. 8 through 11.

A microstrip antenna 100 illustrated in Figs. 8 and 9 is constructed of a dielectric-made substrate 101, a radiation electrode 102 formed on one main surface of the substrate 101, and a ground electrode 103 formed on the other main surface of the substrate 101. Moreover, a power-feeding through-hole 104 is provided at a position corresponding to the radiation electrode 102 on the substrate 101. A connector 105 used for feeding power to the radiation electrode 102 is inserted into and past the feeding through-hole 104 from the other main surface of the substrate 101. The connector 105 is electrically connected to the radiation electrode 102 by means of solder 106a and is fixed to the substrate 101 by means of solder 106a and 106b.

The microstrip antenna 100 constructed as described above receives the circularly polarized wave, and the radiation electrode 102 is accordingly provided with degenerative-mode separating portions 102a, as illustrated in Fig. 8.

A microstrip antenna 110 shown in Figs. 10 and 11 is configured of a dielectric-made substrate 111, a radiation electrode 112 formed on one main surface of the substrate 111, and a ground electrode 113 disposed on the other main surface of the substrate 111. Further, a power-feeding through-hole 114 is provided at a position corresponding to the radiation electrode 112 on the substrate 111. A connector 115 used for feeding power to the radiation electrode 112 is inserted into and past the feeding through-hole 114 from the other main surface of the substrate 111. The connector 115 is electrically connected to the radiation electrode 112 by means of solder 116a and is fixed to the substrate 111 by means of solder 116a and 116b.

The microstrip antenna 110 configured as described above receives the linearly polarized wave, and unlike the radiation electrode 102 of the microstrip antenna 100, the radiation electrode 112 is accordingly free of regenerating separation portions, as shown in Fig. 10.

In the above types of known microstrip antennas there is a great gap between the frequency bands to be received by the respective antennas, and the polarized waves to be received are also different. In order to receive the different frequency bands simultaneously the following techniques are considered:

(1) arranging the two types of microstrip antennas side by side; and
(2) using a microstrip antenna of the type which is able to supply power to two radiation electrode patterns formed on a single substrate.

In either of the techniques, however, the following problems are encountered. The two radiation electrodes respectively corresponding to the different frequency bands should be placed with an ample distance therebetween in order to avoid interference between the frequency bands. Additionally, power-feeding means, such as a connector, should be provided for each of the radiation electrodes, thereby hampering the miniaturization of the antenna.

To solve the above problems, it is an object of the present invention to provide a miniaturized microstrip antenna which copes with a plurality of frequency bands and is also able to select the type of polarized wave.

SUMMARY OF THE INVENTION

In order to achieve the above object, according to the present invention, there is provided a microstrip antenna characterized by: a substrate; a first radiation-electrode formed on one main surface of the substrate; at least one second radiation-electrode formed on the periphery of the first radiation-electrode with a spacing between the first and second radiation-electrodes; a ground electrode formed on the other main surface of the substrate; a power-feeding means formed at a position corresponding to the first radiation-electrode on the substrate; a through-hole formed at a position corresponding to the second radiation-electrode on the substrate; and at least two capacitive-coupling portions for capacitively coupling the first radiation-electrode and the second radiation-electrode.

In the above-described microstrip antenna, the second radiation-electrode may be formed generally in an "L" shape.

In the foregoing microstrip antenna, the capacitive-coupling portions may be each formed in such a manner that a first comb-like electrode projecting from the first radiation-electrode to the second radiation-electrode may be interdigitated with a second comb-like electrode projecting from the second radiation-electrode to the first radiation-electrode.

In the foregoing microstrip antenna, the capacitive-coupling portions may be each formed of a chip capacitor.

With the foregoing arrangements, the first radiation-electrode serves as a microstrip antenna which corresponds to one frequency band. Moreover, the first radiation-electrode is capacitively coupled to the second radiation-electrode so as to form another microstrip line,

thereby serving the function of a microstrip antenna which matches another frequency band. Accordingly, a microstrip antenna which corresponds to a plurality of frequency bands can be formed on a single substrate, and only one feeding through-hole is required to feed power, thereby achieving the miniaturization of the antenna.

Moreover, the second radiation-electrode comprises at least one L-shaped radiation electrode to enlarge the effective area of the microstrip antenna, thereby increasing the gain of the antenna.

Further, since the capacitive-coupling portions are formed in a comb-like shape, a high capacitance can be obtained only with the electrode pattern. This makes it possible to decrease the thickness of the capacitive-coupling portions and also to facilitate the adjustment of the capacitance by means such as trimming.

Additionally, by the use of chip capacitors having the desired capacitances as the capacitive-coupling portions it is possible to obtain a microstrip antenna which is able to receive the frequency bands with high precision and also to reliably select the desired polarized wave.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view illustrating the configuration of a microstrip antenna according to the first embodiment of the present invention.

Fig. 2 is a sectional view taken along the line A-A of Fig. 1.

Fig. 3 illustrates the characteristics of the microstrip antenna according to the first embodiment of the present invention: Fig. 3(a) is a Smith chart; and Fig. 3(b) illustrates the characteristics of the return loss.

Fig. 4 is a plan view illustrating the configuration of a microstrip antenna according to the second embodiment of the present invention.

Fig. 5 is a plan view illustrating the configuration of a microstrip antenna according to the third embodiment of the present invention.

Fig. 6 is a plan view illustrating the configuration in which chip capacitors are used as the capacitive-coupling portions of the microstrip antenna of the present invention.

Fig. 7 is a plan view illustrating the configuration in which degenerative-mode separating portions are provided for the first radiation-electrode of the microstrip antenna of the present invention.

Fig. 8 is a plan view illustrating the configuration of a conventional microstrip antenna.

Fig. 9 is a sectional view taken along the line B-B of Fig. 8.

Fig. 10 is a plan view illustrating the configuration of a conventional microstrip antenna.

Fig. 11 is a sectional view taken along the line C-C of Fig. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be explained while referring to the drawings.

Referring to Figs. 1 and 2, a microstrip antenna 1 includes a dielectric-made substrate 11, a first radiation-electrode 12 formed on one main surface of the substrate 11, second radiation-electrodes 13 and 14 formed on the periphery of the first radiation-electrode 12 with a spacing between the first electrode 12 and each of the second electrodes 13 and 14, a ground electrode 15 disposed on the other main surface of the substrate 11, a power-feeding through-hole 16 provided at a position corresponding to the first radiation-electrode 12 on the substrate 11, a plurality of through-holes 17 provided at positions corresponding to the second radiation-electrode 13 on the substrate 11, and capacitive-coupling portions 18a and 18b for capacitively coupling the first radiation-electrode 12 and the respective second radiation-electrodes 13 and 14.

A connector 19, which serves as a coaxial line, for supplying power to the first radiation-electrode 12 is inserted into and past the feeding through-hole 16 from the other main surface of the substrate 11. The connector 19 is then electrically connected to the first radiation-electrode 12 by means of solder 20a and is fixed to the substrate 11 by means of solder 20a and 20b.

The second radiation-electrodes 13 and 14 are connected to the ground electrode 15 via the through-holes 17.

The first radiation-electrode 12 is formed generally in a square shape, and the second radiation-electrodes 13 and 14 generally in a strip-like shape are respectively placed to face the two sides of the first radiation-electrode 12. The capacitive-coupling portions 18a and 18b are respectively formed in such a manner that first comb-like electrodes 21 and 22 projecting from the first radiation-electrode 12 to the second radiation-electrodes 13 and 14, respectively, are interdigitated with second comb-like electrodes 23 and 24 projecting from the second radiation-electrodes, respectively, to the first radiation-electrode 12. Accordingly, a capacitor is formed between the first radiation-electrode 12 and each of the second radiation-electrodes 13 and 14, thereby establishing capacitive coupling therebetween.

The first radiation-electrode 12, the second radiation-electrodes 13 and 14, and the ground electrode 15 are all formed by etching metal film deposited on both main surfaces of the substrate 11 or by printing and burning a conductive paste on both main surfaces of the substrate 11.

The microstrip antenna 1 constructed as described above functions as an antenna in which the first radiation-electrode 12 corresponds to one frequency band (higher frequency band), and a combination of the first and second radiation-electrodes 12, 13 and 14 correspond to the other frequency band (lower frequency

band).

The results of the test made on the first embodiment are as follows. Fig. 3(a) illustrates a Smith chart illustrating the test results on the impedance characteristics of the first embodiment, and Fig. 3(b) illustrates the characteristics of the return loss of the first embodiment.

In this test, the distance between the center O of the first radiation-electrode 12 and the feeding through-hole 16 was determined to be L1, and the length of a side of the first radiation-electrode 12 was determined to be L12. The feeding through-hole 16 was located at the position which was shifted from the center O toward the second radiation-electrode 13 by an amount equal to the length L1 expressed by the following equation:

$$L1 \approx (1/6) \times L12$$

and power was supplied to the first radiation-electrode 12 at the position of the feeding through-hole 16. Further, the dielectric substrate 11 having a relative dielectric constant of 10.5 was used, and the capacitances of the capacitive-coupling portions 18a and 18b were set to 3.0 pF and 2.5 pF, respectively. The side length L12 of the first radiation-electrode 12 was set to $\lambda_{g1}/2$, and the distance L13 from the farthest edge of the first radiation-electrode 12 to that of the second radiation-electrode 13 was set to $\lambda_{g2}/2$. λ_{g1} and λ_{g2} designate the wavelengths of the higher frequency band and the lower frequency band, respectively.

Figs. 3(a) and 3(b) show that double resonant characteristics in which resonances are produced at f1 = 1.57 GHz and f2 = 2.56 GHz are obtained. It has thus been validated that the microstrip antenna 1 of the present invention copes with a plurality of frequency bands.

An explanation will now be given of a microstrip antenna 30 according to a second embodiment of the present invention while referring to Fig. 4. Elements having the same configuration as those of the microstrip antenna 1 shown in Fig. 1 are designated by like reference numerals, and an explanation thereof will thus be omitted.

The microstrip antenna 30 differs from the microstrip antenna 1 in that a second radiation-electrode 33 generally formed in an "L" shape is located to surround the first radiation-electrode 12.

In this manner, the second radiation-electrode 33 is formed generally in an "L" shape so as to increase the overall effective area including the first and second radiation electrodes 12 and 33, thereby improving the gain of the microstrip antenna 30.

A microstrip antenna 40 according to a third embodiment of the present invention will now be described with reference to Fig. 5. Elements having the same configuration as those of the microstrip antenna 1 shown in Fig. 1 are designated by like reference numerals, and an explanation thereof will thus be omitted.

The microstrip antenna 40 is different from the microstrip antenna 1 in that second radiation-electrodes 43 and 44 are newly provided in addition to the electrodes 13 and 14 to surround all the four sides of the first radiation-electrode 12 which is formed generally in a square shape, and that capacitive-coupling portions 18c and 18d are located between the first radiation-electrode 12 and the second radiation-electrodes 43 and 44, respectively.

The microstrip antenna 40 functions as an antenna in which the first radiation-electrode 12 corresponds to one frequency band, a combination of the first radiation-electrode 12 and the second radiation-electrodes 13 and 14 deals with another frequency band, and a combination of the first radiation-electrode 12 and the second radiation-electrodes 43 and 44 copes with still another frequency band.

In this microstrip antenna 40, as well as in the antenna 30 of the second embodiment, the second radiation-electrodes 13 and 14 may be combined to form a generally "L" shape, and the second radiation-electrodes 43 and 44 may also be combined to form a generally "L" shape, though such a modification is not shown.

In the microstrip antennas described in the first through third embodiments, the first radiation-electrode is capacitively coupled to the second radiation-electrodes via the respective capacitive-coupling portions. The locations of the capacitive-coupling portions may be displaced, and the comb-like electrodes forming the capacitive-coupling portions may be trimmed, thereby readily adjusting the lower frequency band to be received and also selecting the polarized wave on the lower frequency side.

For example, in the microstrip antenna 1 of the first embodiment, the locations of the two capacitive-coupling portions 18a and 18b are displaced and the capacitances of the respective portions are differentiated, thereby causing a phase difference Θ between the resonance produced by capacitive coupling of the capacitive-coupling portion 18a and that of the capacitive-coupling portion 18b. When the phase difference Θ approaches 90°, a circularly polarized wave is produced in the lower frequency side. On the other hand, when the phase difference Θ approaches 0°, a linearly polarized wave is generated in the lower frequency side. In Fig. 3(a), illustrating the test results of the first embodiment, there is shown a constriction indicated by ▽ of the Smith chart of the lower frequency band f1; this constriction represents the state in which a circularly polarized wave is generated in the lower frequency side. In other words, in this microstrip antenna 1, the positions and the capacitances of the capacitive-coupling portions 18a and 18b are set so that a phase difference Θ between the resonance produced by capacitive coupling of the capacitive-coupling portion 18a and that of the capacitive-coupling portion 18b is approximately 90°.

The capacitive-coupling portions formed in the comb-like shape can be simultaneously fabricated with the first and second radiation-electrodes. This makes it possible to easily form the capacitive-coupling portions and to also make the thickness of the portions equal to that of the electrodes.

Although in the first through third embodiments the capacitive-coupling portions are formed of comb-like electrodes, they may be formed by chip capacitors 38, as illustrated in Fig. 6. In this case, since chip capacitors having the desired capacitances can be selected, it is possible to readily and correctly fabricate an antenna which copes with the required frequency bands and required polarized wave. By virtue of this modification, the process steps of adjusting the frequency and re-selecting the polarized wave are unnecessary. It should be noted that the elements shown in Fig. 6 other than the chip capacitors 38 are the same as those of the microstrip antenna 30 explained in the second embodiment, and an explanation thereof will thus be omitted.

The mode of the capacitive-coupling portions is not restricted to the foregoing embodiments, but may be modified according to the purpose or the use of the microstrip antenna. For example, the capacitive-coupling portions, which are placed where the first and second radiation-electrodes can be capacitively coupled, may be configured in a laminated structure in which a dielectric layer is interposed between the first radiation-electrode and the second radiation-electrodes, though such a modification is not shown.

Further, the first radiation-electrode 12 of each embodiment may be configured, as illustrated in Fig. 7, to have degenerative-mode separating portions 12a so as to select the type of polarized wave of the higher frequency side to be received by the first radiation-electrode 12. It should be noted that the elements shown in Fig. 7 other than the degenerative-mode separating portions 12a are the same as those of the microstrip antenna 1 of the first embodiment, and an explanation thereof will thus be omitted.

In this manner, according to the microstrip antenna of the present invention, the first radiation-electrode which copes with one frequency band (higher-frequency band) is able to set the type of polarized wave, and a combination of the first and second radiation-electrodes is also capable of selecting the type of polarized wave.

Although in the foregoing embodiments the first radiation-electrode is formed generally in a square shape, it may be formed generally in a circular shape.

In the foregoing embodiments, the second radiation-electrodes are connected to the ground electrode via a plurality of through-holes. If, however, the second radiation-electrodes are grounded in a high frequency band, the number of through-holes may be determined as required.

As is seen from the foregoing description, the microstrip antenna of the present invention offers the following advantages: The first radiation-electrode serves as a microstrip antenna which corresponds to one frequency band. Moreover, the first radiation-electrode is capacitively coupled to the second radiation-electrodes so as to form another microstrip line, thereby serving the function of a microstrip antenna which copes with another frequency band. Accordingly, a microstrip antenna which matches a plurality of frequency bands can be formed on a single substrate, and only one feeding through-hole is required to feed power, thereby achieving the miniaturization of the antenna.

Moreover, the second radiation-electrodes are formed generally in an "L" shape so as to enlarge the effective area of the microstrip antenna, thereby increasing the gain of the antenna.

Further, since the capacitive-coupling portions are formed in a comb-like shape, a high capacitance can be obtained only with the electrode pattern. This makes it possible to decrease the thickness of the capacitive-coupling portions and also to facilitate the adjustment of the capacitance by means such as trimming, thereby receiving the frequency bands with high accuracy and enabling the selection of the type of polarized wave.

Additionally, by the use of chip capacitors having the desired capacitances as the capacitive-coupling portions it is possible to obtain a microstrip antenna which is able to receive the frequency bands with high precision and also to select the desired polarized wave.

Claims

1. A microstrip antenna characterized by:

    a substrate (11);
    a first radiation-electrode (12) formed on one main surface of said substrate (11);
    at least one second radiation-electrode (13, 14; 33; 13, 14, 15, 16) formed on the periphery of said first radiation-electrode (12) with a spacing between said first and second radiation-electrodes;
    a ground electrode (15) formed on the other main surface of said substrate (11);
    a power-feeding means (16) formed at a position corresponding to said first radiation-electrode (12) on said substrate (11);
    a through-hole (17) formed at a position corresponding to said second radiation-electrode on said substrate (11); and
    at least two capacitive-coupling portions (18a, 18b; 18a, 18b, 18c, 18d) for capacitively coupling said first radiation-electrode and said second radiation-electrode.

2. The microstrip antenna according to claim 1, characterized in that said second radiation-electrode (33) comprises at least one L-shaped radiation electrode.

3. The microstrip antenna according to claim 1 or 2, characterized in that said capacitive-coupling portions are each formed in such a manner that a first comb-like electrode (21, 22) projecting from said first radiation-electrode to said second radiation-electrode is interdigitated with a second comb-like electrode (23, 24) projecting from said second radiation-electrode to said first radiation-electrode.

4. The microstrip antenna according to claim 1 or 2, characterized in that said capacitive-coupling portions are each formed of a chip capacitor (38).

FIG. 1

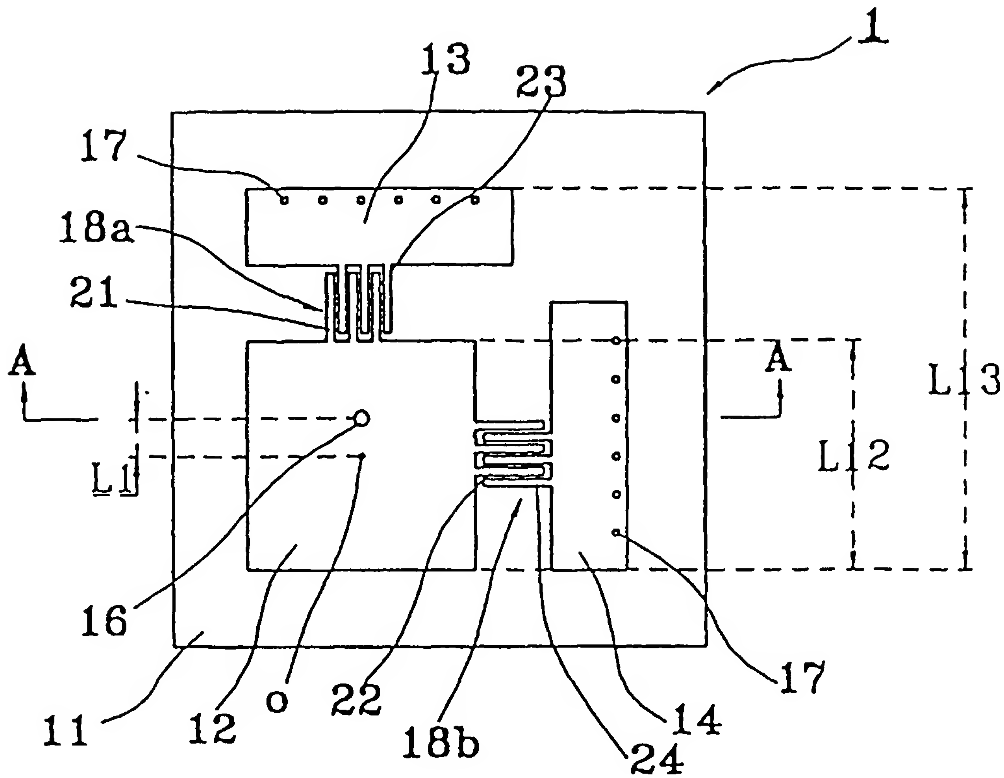

1
13
23
17
18a
21
A
A
L1
L2
L3
16
11
12
o
22
18b
24
14
17

FIG. 2

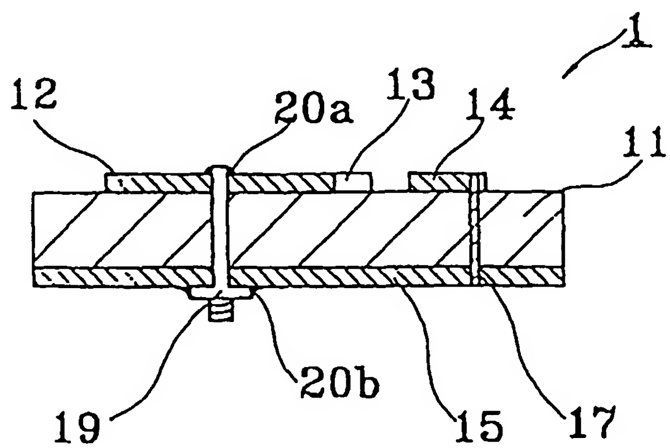
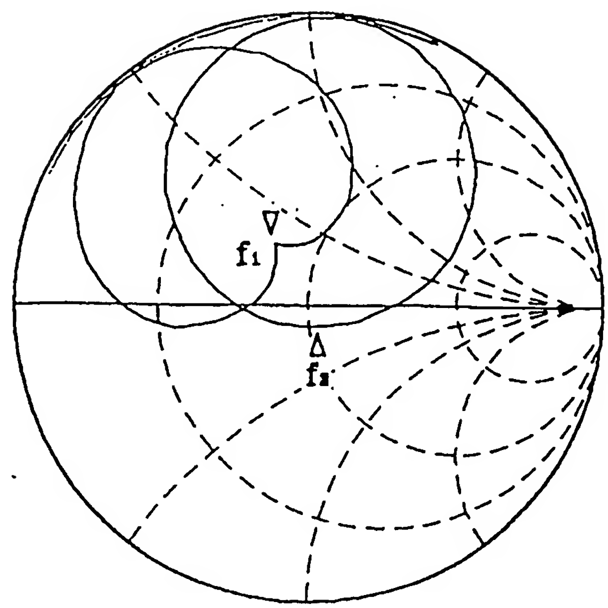
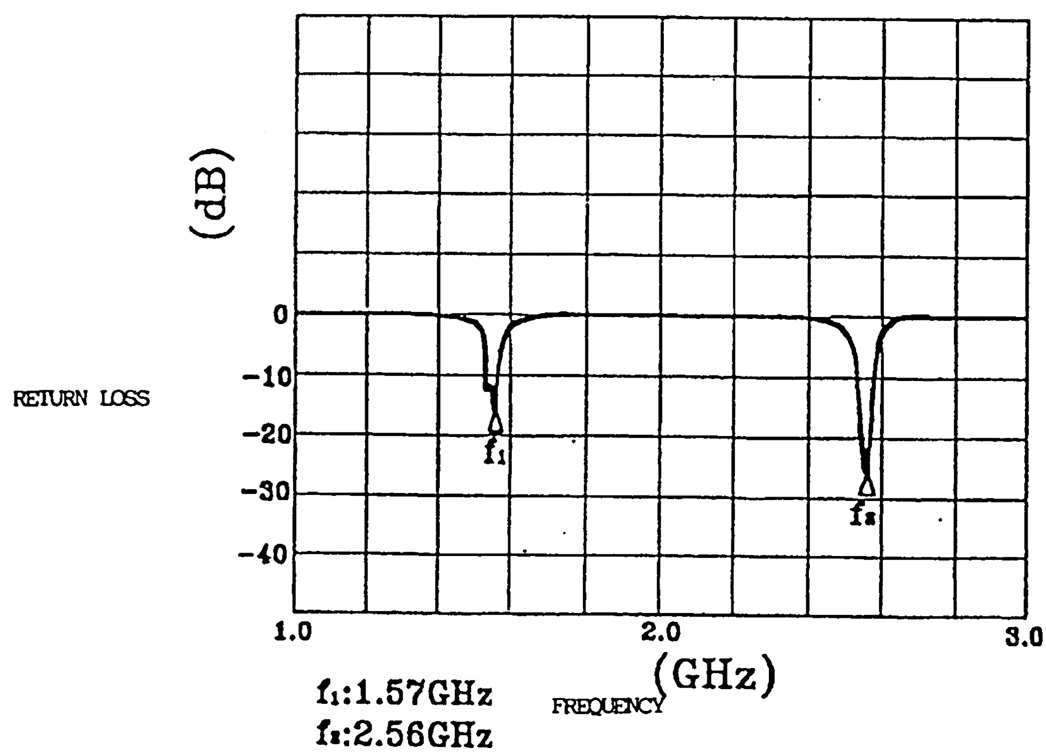

1
12
20a
13
14
11
19
20b
15
17

FIG. 3


f1
f2

(a)


(dB)
RETURN LOSS
0
-10
-20
-30
-40
f1
f2
1.0
2.0
3.0
(GHz)
FREQUENCY
f1:1.57GHz
f2:2.56GHz

(b)

FIG. 4

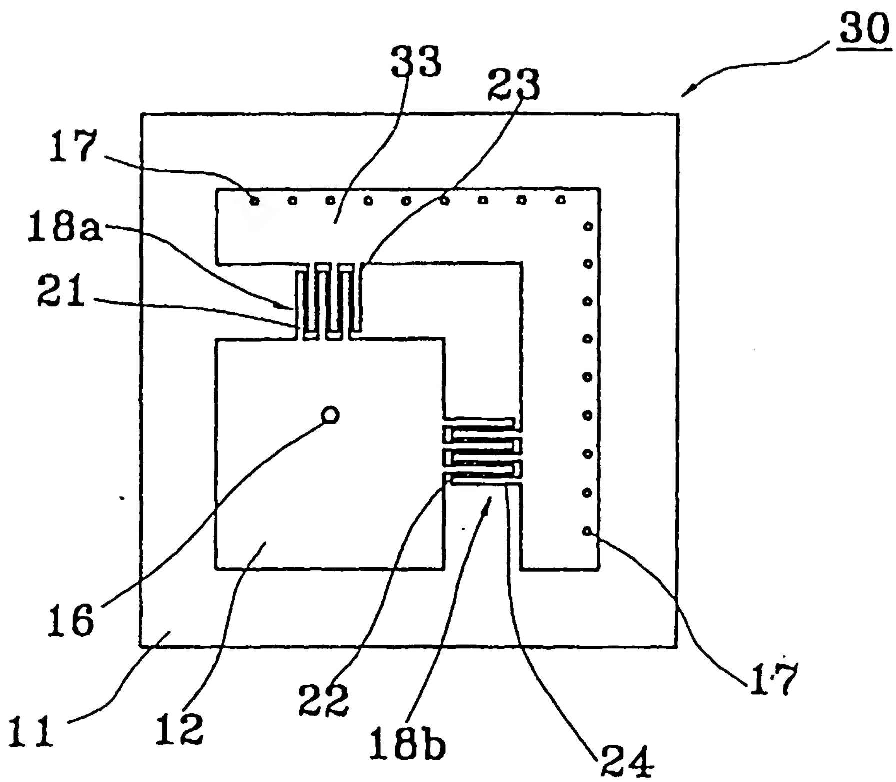


FIG. 5

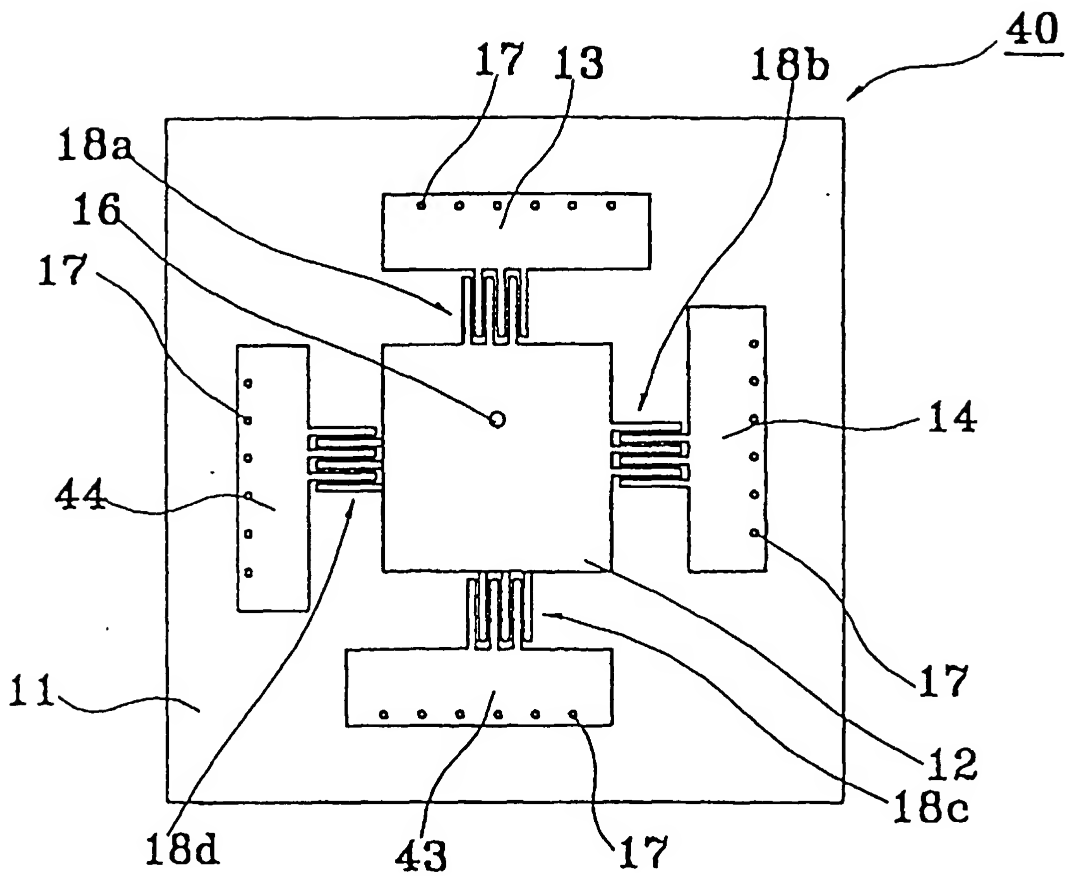


FIG. 6

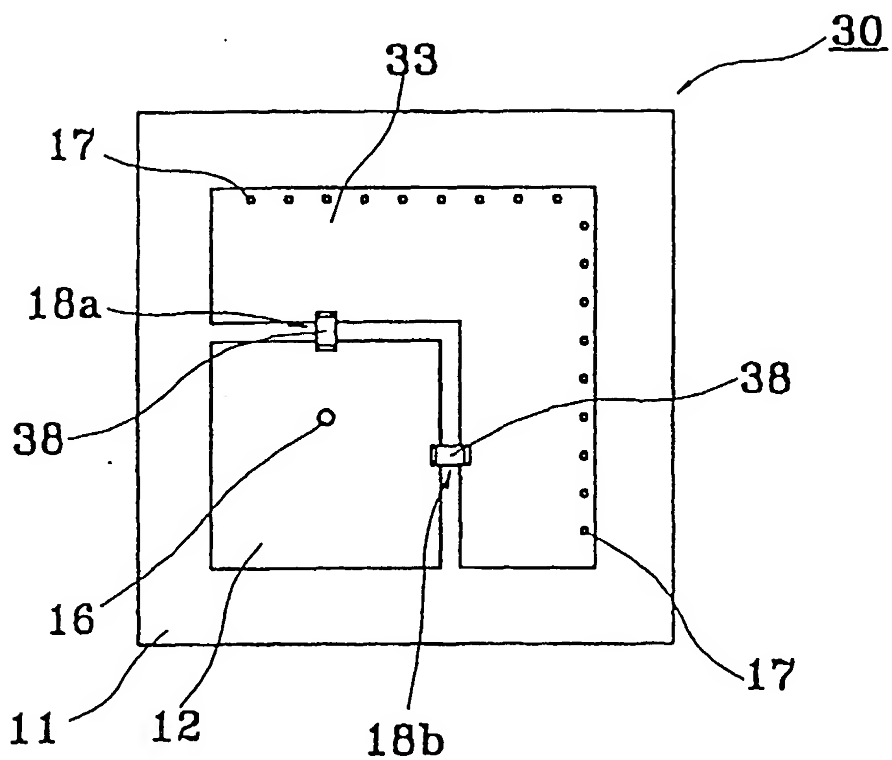


FIG. 7

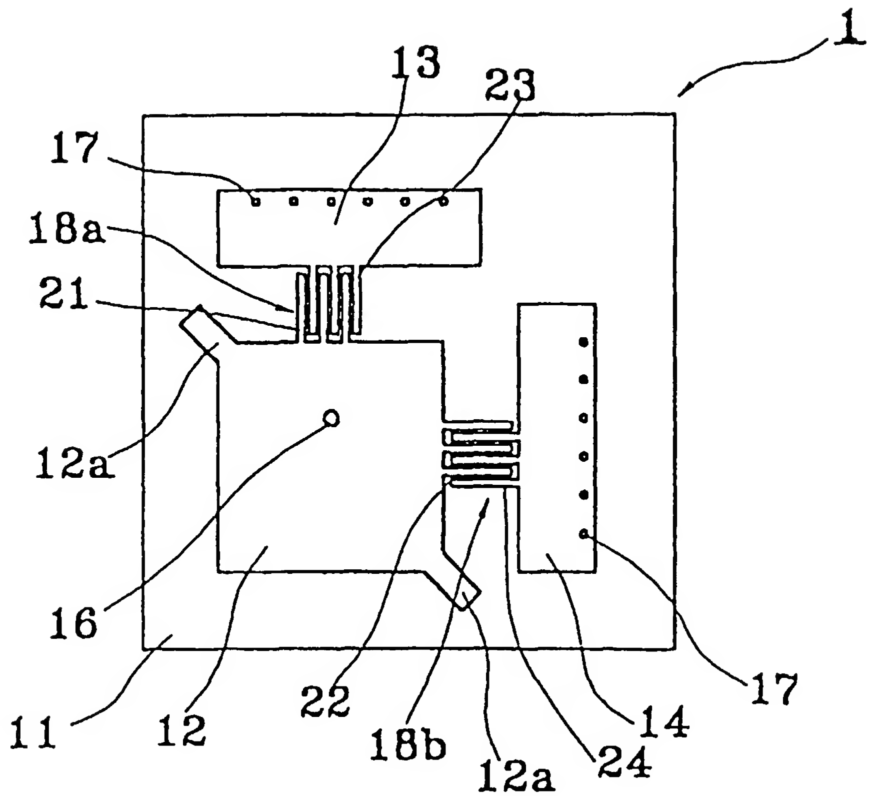

1
13
23
17
18a
21
12a
16
11
12
22
18b
12a
24
14
17

FIG. 8

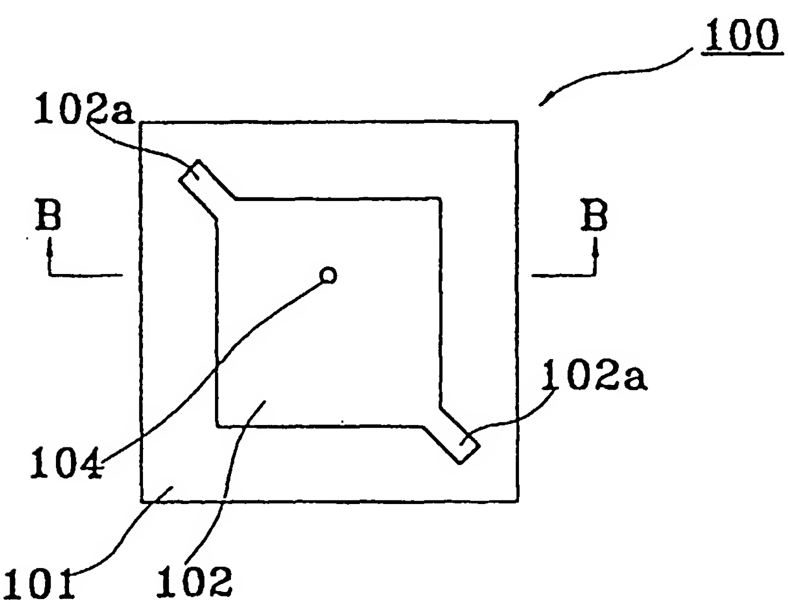

100
102a
B
B
102a
104
101
102

FIG. 9

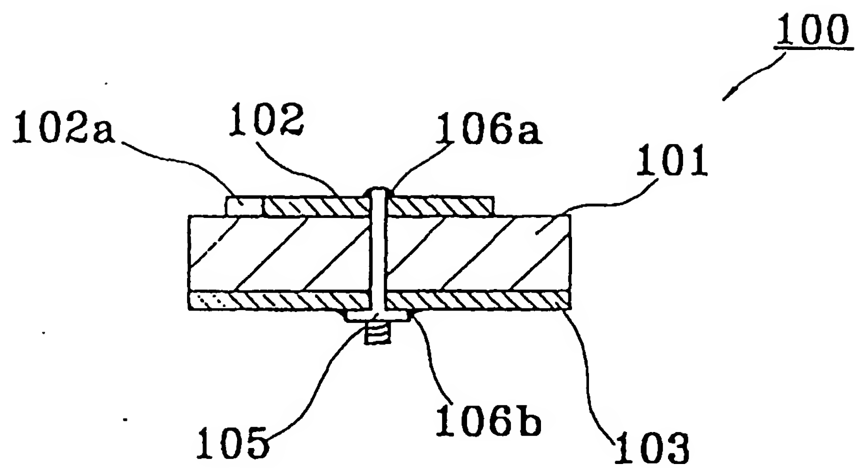


FIG. 10

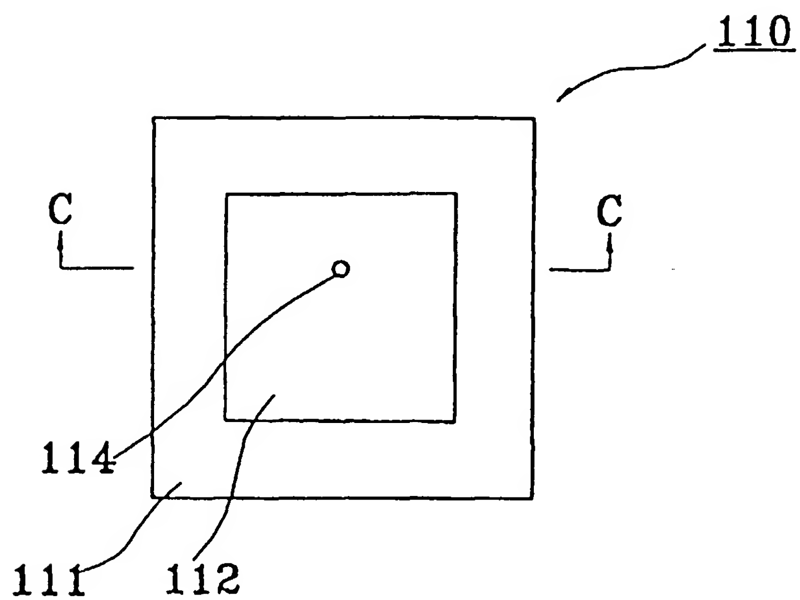


FIG. 11